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Acacia × *mangiiformis* hybrida nova (Leguminosae: Mimosoideae), a wattle of commercial importance in Asia

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Abstract

Acacia × *mangiiformis* Maslin & L.A.J.Thomson, *hybrida nova*, is described. Its parents are *Acacia auriculiformis* A.Cunn. ex Benth. and *A. mangium* Willd., two well-known and important plantation species in Asia and elsewhere. *Acacia* × *mangiiformis* arose naturally in the Western Province of Papua New Guinea and in recent decades has become widely cultivated in southeast Asia (Indonesia, Malaysia, Thailand and Vietnam), India, and to a lesser extent in China and Taiwan. The tree has often been referred to as "*Acacia* hybrid" in forestry literature.

Acacia × *mangiiformis* has morphological and other characteristics that are intermediate between its parents. Furthermore, it often has a faster growth rate, superior bole form and is more drought-tolerant than its parent species.

The hybrid is used primarily for pulp production but also has uses as solid wood products and fuelwood. The wood is similar to that of *A. mangium* but has a higher density and is more suitable for products where strength is important; it is also less susceptible to termite attack than are its parent species. Ten high-performing commercial clones of *Acacia* × *mangiiformis* have been developed in Vietnam and more are being selected.

The formal naming of this important hybrid is dedicated to Professor Le Dinh Kha (formerly of Forest Science Institute of Vietnam), an outstanding researcher, supervisor, and authority on tree breeding who conducted much of the original research and promotion of *Acacia* × *mangiiformis* in Vietnam.

Introduction

Acacia auriculiformis A.Cunn. ex Benth. and *A. mangium* Willd. are important species in tropical forestry plantation industries, especially in southeast and India. The natural distributions of both species extend from northern Australia to nearby areas of Papua New Guinea and eastern Indonesia (Fig. 1). A putative hybrid between *A. auriculiformis* and *A. mangium* was first detected in plantations by Hepburn and Shim in early 1972, when it was found growing among introduced trees of *A. mangium* in Sook Telupid, Sabah, Malaysia (Tham 1976, FAO 1982).

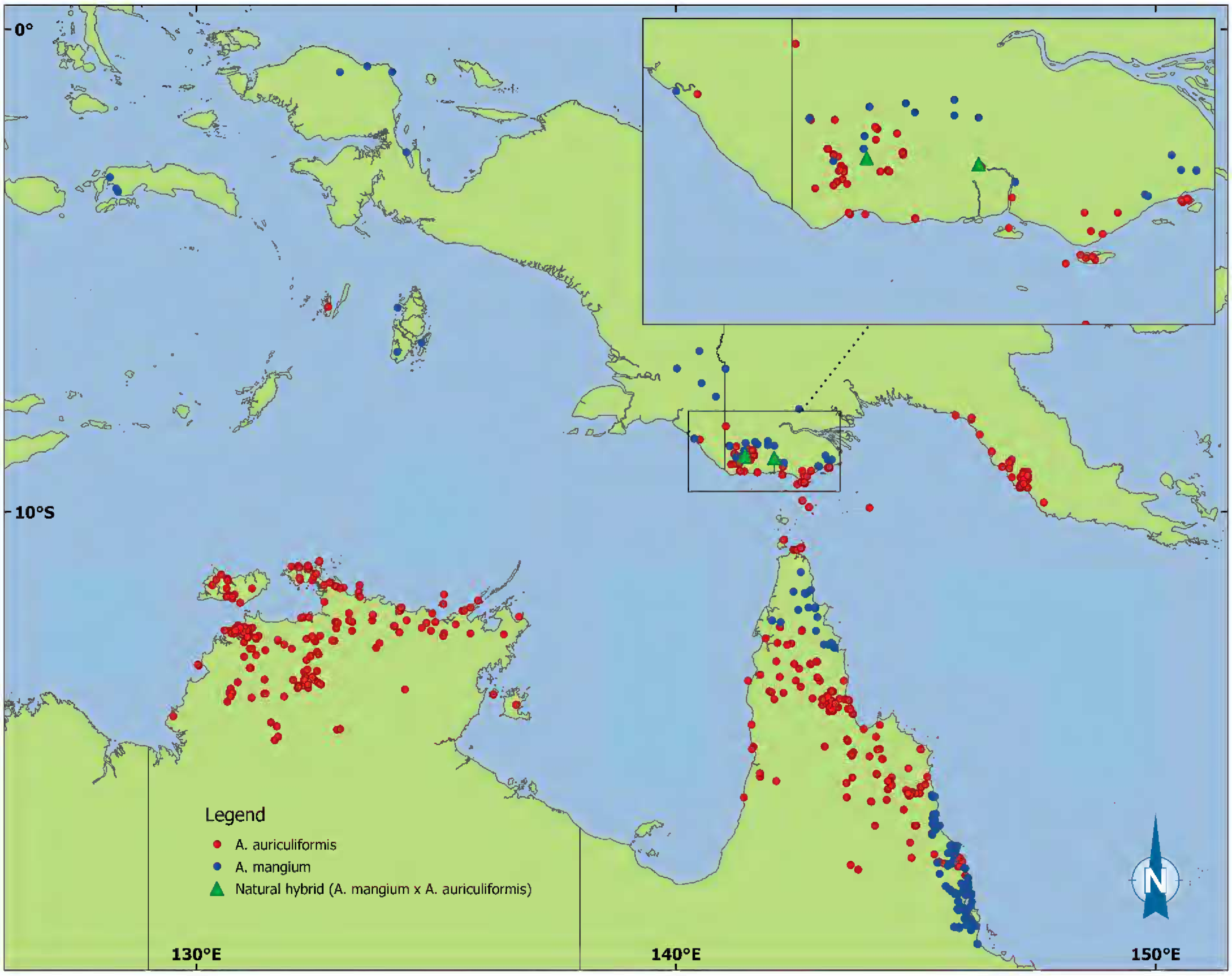


Fig. 1. Natural distribution of *Acacia auriculiformis*, *A.* × *mangiiformis* and *A. mangium* in northern Australia, New Guinea and islands of eastern Indonesia.

In 1986, staff of the Australian Tree Seed Centre, CSIRO, Canberra, collected a putative hybrid between *Acacia auriculiformis* and *A. mangium* found in natural stands including these two species in the Western Province of Papua New Guinea (see *Thomson and Cole LXT 662*, specimen cited below), where it was scattered and rare. In this province, *A. auriculiformis* occurs close to rivers and drainage lines, whereas *A. mangium* is found in secondary forests throughout the area; the hybrids are also found near drainage lines. Kha (2000, 2001) provided a synopsis of the early detection and experimental plantings of the hybrid (derived from individuals arising spontaneously in plantations), recording it also from China, Indonesia, Taiwan and Thailand.

The most extensive work and development of the hybrid was in Vietnam and East Malaysia, two territories where it is now extensively cultivated. In Vietnam hybrid trees were originally found occurring spontaneously in several provinces (including Ninh Tuan, Bình Duong and Quang Nam, Thomson 1994) where one or other or both of the parents grew in planted stands. Subsequently in Vietnam the hybrids were found among seedlings derived from the parents that had been raised from *A. auriculiformis* and *A. mangium* originating from natural populations in Northern Territory and Queensland, Australia (Kha 2000, 2001). These Vietnamese hybrid plants displayed a faster growth rate than that of *A. mangium* (Kha 2001) and seemed more drought-tolerant than *A. auriculiformis* (Thomson 1994) so that such hybrids were selected for plantations.

Subsequent research demonstrated the intermediate nature of the hybrid plants with respect to adult phyllode morphology, seedling ontogeny, and isozymes (Kha 2001 provides an excellent summary and references). Conclusive evidence for the status of the putative hybrids between *Acacia mangium* and *A. auriculiformis* includes reciprocal crosses (Sedgley *et al.* 1992) and molecular studies using single nucleotide polymorphism markers (Yuskianti *et al.* 2011) and microsatellite markers (Son *et al.* 2016).

The most recent estimates put the plantation area of the hybrid *A. auriculiformis* × *A. mangium* at 550,000 ha in Vietnam (Vietnam's Ministry of Agriculture and Rural Development unpublished, cited in Son *et al.* 2018), with an annual increase in plantation area of c. 30,000-35,000 ha (Kha and Thinh 2017). In Vietnam it is used primarily for pulp production but also having secondary uses for solid wood products and as a fuelwood

(Griffin *et al.* 2011). Ten high-performing commercial clones of the hybrid have been selected in Vietnam; these vegetatively-propagated clones make up most of the plantations in the country: research to identify and increase the number of high-performing clones that can be deployed in the field is in progress (Son *et al.* 2018).

In Malaysia there has been research on the hybrids, including clonal selection and development of micropropagation protocols in Sabah during the 1990s (Galiana *et al.* 2003), wood properties in Sarawak (Jusoh *et al.* 2014) and carbon sequestration (Adam and Jusoh 2018). In Indonesia the putative hybrid was found to be widespread in *A. mangium* plantations on Pulau Laut, southern Kalimantan and south Sumatra (Thomson 1993, Wong 1993). The F_1 hybrid out-performed the parental species in terms of both growth rate and superior bole form. The potential of the hybrid was soon realised and research to assess growth characteristics and performance under cultivation in Indonesia and elsewhere ensued. The hybrid is expected to become more widely planted in the future due to its better growth and wood properties, and tolerance to pests and diseases (by contrast with its parental species) and a breeding program has been planned (Sunarti *et al.* 2013). In India the hybrid has been planted on a large scale for production of pulpwood in Karnataka (Amanulla *et al.* 2004).

Ceratocytis spp. (including *C. manginecans*, Ceratocystidaceae) are major fungal problem for *Acacia* plantations, especially *A. mangium*, in humid zones of southeast Asia (Nasution *et al.* 2019). Preliminary screening in Vietnam has shown a range of genetic tolerance to this fungus in *Acacia auriculiformis* and the hybrid, but no tolerance in *A. mangium* (Kien *et al.* 2017). Nambiar *et al.* (2018) raised the prospect of developing disease-tolerant *Acacia* hybrid clones, combining the desired attributes of both species, through advanced generation hybrid breeding and/or polyploid breeding.

Up to now the *A. auriculiformis* × *A. mangium* hybrid has usually been referred to, as "*Acacia* hybrid" in the forestry literature. This is an informal appellation, one that has the potential to cause confusion since other interspecific *Acacia* hybrids are already known. We therefore consider it timely to provide a formal name for this economically important hybrid, a name formed in accordance with the International Code of Nomenclature (Turland *et al.* 2018), because this provides nomenclatural precision. The name, *Acacia* × *mangiiformis* which is proposed below, applies to all hybrid combinations involving *Acacia auriculiformis* and *A. mangium*, irrespective of whether they are F_1 or F_2 hybrids including back-crosses, or which parent is the mother plant (see ICN Article H.4). However, it should be noted that the description of *Acacia* × *mangiiformis* below is based on specimens of the F_1 hybrid plants that we cite. Should these additional hybrids (or individual clones of *Acacia* × *mangiiformis*) need to be individually recognized, they are best given cultivar names in accordance with the International Code of Nomenclature for Cultivated Plants (Brickwell *et al.* 2009).

Taxonomy

Acacia* × *mangiiformis Maslin & L.A.J.Thomson, *hybrida nova*

Type: Papua New Guinea, Western Province, 300 m E of Jari River mouth along Mai Kussa River, 08º53'S 142º03'E, 18 Oct 1988, *M.W.McDonald MM 817* (holotype: PERTH 04189205; isotypes *(n.v.)*: AD, BRI, CANB, DNA, LAE, MEL).

"*Acacia* × *manauriculiformis*" Kha (2001), *nom. nud.*

Distinctive features. *Penultimate branchlets* slender and terete. *Phyllodes* 120–180 mm long, 22–40 (–50) mm wide, length: width = 4.5–7, shallowly falcately recurved or sometimes straight and dimidiate, with numerous longitudinal minor veins moderately anastomosing to form very elongated, poorly-defined vein islands; gland 1–2 mm above pulvinus. *Inflorescence spikes* creamy white to very pale lemon yellow. *Calyx tube* hairy. *Pods* regularly once to twice spirally coiled, 6–8 mm wide, oval in section, not undulate. *Funicle/aril* much folded beneath the seed (not encircling it), 30–35 mm long (expanded length).

Description. *Trees* to 25 m tall with dbh to *c.* 80 cm, typically with ± straight, cylindrical bole and fine horizontal branching (F_1 in plantation), but with spreading form and heavy branching in older, open-grown individuals. *Branchlets* slender, angled at extremities but soon terete, glabrous. *Phyllodes* narrowly elliptic and shallowly falcately recurved, sometimes straight and dimidiate (i.e. lower margin straight and upper margin convex), 120–180 mm long, 22–40 (–50) mm wide, length: width= 4.5–7, narrowed at base, glabrous; *main longitudinal veins* 3 (or sometimes 4 or 5), running together at phyllode base but remaining separate from lower marginal vein; *minor longitudinal veins* fine and numerous, 3–5 per mm, clearly distant (mostly 0.3–0.5 mm apart), with moderately numerous longitudinal anastomoses (vein islands very elongated, irregular and not especially well-defined); *apex* narrowed to an innocuous, blunt, eglandular point; *pulvinus* 5–8 mm long. *Gland* situated 1–2 mm above pulvinus, submerged within the lamina which is slightly swollen about the gland and the

phyllode margin often slightly but discernibly raised at the gland when dry. *Inflorescences* comprising 1 or 2 shortly pedunculate spikes within axil of phyllodes, prolific and showy; *spikes* 70–100 mm long, creamy white to very pale lemon yellow, the flowers not densely arranged within the spikes; *receptacle* very sparsely hirtellous when in flower, glabrous in pod; *peduncles* 6–10 mm long, glabrous or with very short, straight, appressed, silvery white hairs. *Flowers* 5 merous, sessile; *calyx* gamosepalous, *c.* ½ length of corolla, with short broadly triangular lobes, calyx tube white-puberulous; *petals c.* 2 mm long, joined for *c.* ½ their length, strongly reflexed following anthesis (± appressed to the calyx); *stamens* indefinite, free. *Pods* regularly once- or twice-spirally coiled, coils mostly 20–25 mm wide, the valves 6–8 mm wide, flat, coriaceous to thickly crustaceous, glabrous and dark brown. *Seeds* longitudinal in pods, oblong to slightly elliptic, 5–5.5 x 3.5 mm, compressed (*c.* 1.5 mm thick), brown, shiny; *pleurogram* elongated 'u'-shaped, open at hilar end, 4 x 2 mm; *funicle* and *aril* pale yellow (when dry), much folded beneath the seed but not encircling seed, 30–35 mm long (expanded length upon hydration).

Other specimens examined (paratypes). MALAYSIA. Planted from mother tree from Australia, Malaysia Perak, Hilir Perak, Bidor sub-station, FRIM field station, 1 Sep 2004, *C.H.Ng* FRI 49124 (KEP 75000). SINGAPORE: Pulau Ubin, *Ali, S.L. Koh & L. Joseph* PU 2014-006 (SING 0226779, SING 0244802).PAPUA NEW GUINEA: Wemenever, Western Province, 8°51'S, 141°26'E, 1 Oct 1986, *L.Thomson & E.G.Cole LXT 662* (CANB 721789.1).

Distribution. Occurs naturally in Western Province of Papua New Guinea,see above (Fig. 1). Widely cultivated in southeast Asia (Indonesia, Malaysia, Thailand and Vietnam) and India, and to a lesser extent in East Asia (China and Taiwan).

Phenology. In Papua New Guinea the peak flowering of the natural populations occurs from about April to June, with mature seeds present from mid to late September to early November. However, in cultivation in areas north of the equator, the phenology is different. For example, in Vietnam plants flower from about September to January and have mature seeds from about March to June.

Recognition. Acacia auriculiformis, *A.* × *mangiiformis* and *A. mangium* are members of *Acacia* sect. *Juliflorae* (Benth.) Maiden & Betche, a group defined by having phyllodes with numerous longitudinal veins and flowers in cylindrical spikes. Other distinctive characters shared by these mostly glabrous species include their arborescent form, their phyllodes having main veins running together at the base but remaining separate from lower marginal nerve, very shortly dissected calyces, strongly curved to coiled pods and brightly coloured seed funicle/arils (most commonly bright yellow or orange). In nature *Acacia auriculiformis* and *A. mangium* co-occur in tropical areas of far northeast Queensland and New Guinea (Fig. 1).

The distinctive features of the hybrid, when taken in combination, serve to distinguish adult plants from those of its parents. Among this suite of characters are some that are shared with one or other of the parents and some that are ±intermediate between the parents (see Table 1). *Acacia* × *mangiiformis* resembles *A. auriculiformis* in having slender, terete penultimate branchlets (stout and acutely angled in *A. mangium*), often falcately recurved phyllodes (straight in *A. mangium*) and non-undulate pods (outer edge of pod valve undulate in *A. mangium*); it resembles *A. mangium* in having a hairy calyx (glabrous in *A. auriculiformis*) and a funicle/aril that does not encircle the seed (partially or wholly encircling seed in *A. auriculiformis*). The characters where *Acacia* × *mangiiformis* is more or less intermediate between its parents include phyllode size and the frequency of their anastomosing minor veins, gland distance above the pulvinus, spike colour, pod valve width and funicle/aril length.

For plants in cultivation in Asia (Sabah, Thailand and Vietnam), it has been reported by Rufelds (1988), Royampaeng *et al.* (1998), Sein and Mitlöhner (2011) and Kha (2001) that although hybrid plants have some unique characters, they also exhibit a range of other characters that are intermediate between the parents, e.g. stem and crown form, wood density and seedling leaf and juvenile phyllode development and morphology. Often these studies also demonstrated that adult phyllodes of hybrid plants were intermediate between those of the parents, but the dimensions recorded varied slightly between the studies (and also varied from those recorded here). However, this is not considered significant because there is variation correlated with differing environmental conditions under which plants are grown. The phyllodes of hybrid plants are generally wider than those of *A. auriculiformis*, but narrower than those of *A. mangium*.

Utilisation. The wood of *A.* × *mangiiformis* is similar to that of *A. mangium* but it has a higher density, is more suitable for products where strength is important (Griffin *et al.* 2011) and is less susceptible to termite attack when compared to wood of the parental species (Jusoh *et al.* 2014). As reported by Sein and Mitlöhner (2011) the wood is used for construction, boat-building, furniture, cabinet making and veneering. It also makes excellent particle board and its pulp is easy to bleach and is excellent for paper-making. *Acacia* × *mangiiformis* is also used for firewood, and is occasionally planted for erosion control, as a firebreak or for ornament; its phyllodes can also be used as forage for cattle.

Character	***Acacia auriculiformis***	***Acacia* × *mangiiformis***	***Acacia mangium***
Penultimate branchlets	Slender & terete	Slender & terete	Stout and acutely angled
Phyllode curvature	Shallowly to obviously falcately recurved, occasionally straight & dimidiate	Shallowly falcately recurved, sometimes straight & dimidiate	Straight, often dimidiate
Phyllode dimensions			
length	(120–) 140–220 mm	120–180 mm	(130–) 150–240 (–270) mm
width	(10–) 15–30 (–40) mm	20–40 (–50) mm	(30–) 40–75 mm
l:w	(4–) 6–10 (–13)	4.5–7	3–4 (–5)
Phyllode minor veni anastomoses	Normally relatively few & not forming vein-islands; rarely moderately numerous, & forming poorly-defined, elongated vein-islands	Moderately numerous, forming very elongated, poorly-defined vein- islands	Numerous, forming distinct reticulum with elongated vein-islands
Gland distance above pulvinus[1]	0–1 mm above pulvinus[1]	1–2 mm	(1–) 2–3 (–4) mm
Spike colour	Light golden to golden	Creamy white to very pale lemon yellow	White to off-white
Calyx tube indumentum	Glabrous	Hairy	Hairy
Pods curvature	Strongly curved to once, twice or more spirally coiled, often irregularly so	Regularly once to twice spirally coiled	Strongly curved to 1½ (–2) coiled, often irregularly so
Pod valve undulation	Not undulate	Not undulate	Outer edge moderately to strongly undulate
Pod valve width	(3–) 4–5	6–8	10–22 mm
Pod t.s. shape[2]	Terete	Oval	Flat
Funicle/aril	½–¾, or wholly encircling seed in a single or double fold; 25-55 mm (expanded length).	Not encircling seed (but much-folded beneath them); 30–35 mm long (expanded length)	Not encircling seed (but much folded beneath them and sometimes extending to ½ way down one side of seed); 12-18 (-25) mm long (expanded length).

Table. Morphological characters of mature plants that distinguish *Acacia* × *mangiiformis* from its parents, *A. auriculiformis* and *A. mangium*. Data derived from range of herb. PERTH specimens of *Acacia auriculiformis* and *A. mangium*, and the specimens of *A.* × *mangiiformis* cited above (unless otherwise stated).

Notes: [1]Gland reported as absent in the hybrid (*Acacia* × *mangiiformis*) by Kha (2001: 38), however, this would be very atypical for the species. Data from Kha (2001)

Etymology. The species epithet combines elements of the parent species names.

Dedication. We take great pleasure in dedicating this new hybrid to Professor Le Dinh Kha. Professor Kha is former Director of the Research Centre for Forest Tree Improvement (now Institute of Forest Tree Improvement and Biotechnology, Institute of Forest Tree Improvement and Biotechnology, Hanoi, Vietnam), an outstanding researcher, supervisor, and authority on tree breeding. Professor Kha established one of the premier research centres under the Forest Science Institute of Vietnam and conducted research on selection and promotion of the species including the 2001 publication on "Studies on the use of natural hybrids between *Acacia mangium* and *Acacia auriculiformis* in Vietnam".

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